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INTEGRATED CIRCUIT WITH A SENSOR ELEMENT

The invention relates to an integrated circuit arrangement with a sensor element.

Integrated circuit arrangements with sensor elements, e.g. with magnetic sensors, are known, which detect mechanical switching states in a large number of consumer and automotive applications. They detect a mechanical switching state by means of a variable magnetic field, which represents the changed position on the basis of a variable distance between the magnetic field sensor and a movable magnet. The physical variable of magnetic field strength is thus used as a measure for determining the switching state. If the magnet approaches the transducer, which converts the magnetic field strength into an analog electrical signal, the switching state "turned on" is represented at the output of the sensor circuit when the distance becomes less than a certain distance A1. If the distance becomes less than a further distance A2, the output signal represents "turned off". This clearly shows that this sensor circuit can exactly represent a switching state as either "turned on" or "turned off". If significantly differentiated, more manifold switching states are to be represented, it is necessary to use a cascade of such sensor circuits, which requires very complex total circuits, which are very bulky and costly. In addition, such total circuits prove to be highly trouble-prone. Furthermore, such total circuits have a high EMC risk, which is a great disadvantage in the automotive field.

It is the object of the invention to create an integrated circuit arrangement with a sensor that can represent differentiated switching states, that is more than just one "turned on" or "turned off" switching state, and thus overcomes the above-mentioned disadvantages as completely as possible.

The invention accomplishes this object by a sensor arrangement with the characteristics of Claim 1.

Advantageous developments are found in the subclaims.

The inventive circuit arrangement, which can represent more switching states than only "turned on" or "turned off", comprises a control unit to control the sensor circuit, and an input to which an analog electrical signal is conducted.

This signal corresponds to an analog physical variable, such as pressure, force, acceleration, magnetic field strength, electromagnetic field strength, temperature, light intensity, or the like. This electrical input signal is compared with several thresholds in an analytical unit or a comparator unit. If the value of the signal falls above or below these individual thresholds, an output signal is generated which can represent a number of different switching states, which extend beyond the single switching state of "turned on" or "turned off". This output signal is conducted from the analytical unit or comparator unit to

the output stage and is made available to the environment of the sensor circuit for further use.

The invention thus succeeds in representing various differentiated switching positions by means of a single sensor circuit, which comprises a single control unit, a single analytical unit, a single output stage, and a single input, and which is especially simple, compact, and reliable. For example, this can be used in connection with the contact-free picking off of the many positions of the wiper lever in an automobile by means of Hall sensors and an appropriate, series-connected, inventive sensor circuit. The many various positions of the wiper lever, such as, for example, "off", "on slow", "on fast", "on very fast", or "timed operation", are converted by such an arrangement with the inventive sensor circuit into an electrical output signal, which can uniquely and discretely represent these many switching states. According to the invention, a cascade arrangement of several sensor circuits, as is the case in the prior art, can be dispensed with. This is associated with a considerable reduction of costs, of the space needed for the circuits, of the complexity of the circuit and wiring, with a marked reduction of trouble-proneness, as a result of the reduction in the number of components, and with an improvement as regards EMC sensitivity, due to the reduction of EMC-sensitive components and EMC-generating components. The inventive sensor arrangement is thus best suited for the automotive field, which precisely has special requirements for EMC compatibility and compact arrangements.

In addition, this sensor circuit proves to be a very universal sensor circuit, since it can interact with the most various transducers for converting various analog physical variables into analog electrical signals. In this case, the analog electrical signal only needs to be amplified to a certain amplitude range by an appropriate signal amplifier, and then conducted to the input and matched to the thresholds, as appropriate.

According to a preferred design of the invention, the transducer for converting the analog physical variable into an analog electrical input signal is connected to the single input, and thus is integrated into the sensor circuit. This makes it possible to adapt the transducer and sensor optimally to the remaining sensor circuit, and thus to create a closed and standardized sensor circuit, which no longer requires any specific adjustment by the user. This eliminates a great deal of trouble associated with such a standardized circuit with a transducer, especially if the user, when adapting the output signal of the transducer to the remaining circuit, does not correctly take into account the relationships with the threshold values. This regularly results in considerable problems regarding the unambiguous nature of the output signal and thus regarding the representation of the plurality of discrete circuit states. Furthermore, it is now possible to design the standardized sensor circuit with a transducer especially optimized as regards space and EMC, since the interactions of the transducer with the remaining sensor circuit can already be taken into account in the design.

The sensor circuit preferably has an output stage with a single output. At this output, the plurality of discrete circuit states is represented, for example, by the pulse/pause ratio of the output signal or by a digital signal, which is not necessarily binary coded, or by an analog signal, which has a number of signal steps, corresponding to the plurality of switching states. For example, if five switching states are to be represented, the pulse/pause ratio can vary between 5/1, 4/2, 3/3, 2/4, and 1/5. Besides these examples, one can also conceive of other ways of representing the plurality of switching states with a single output. The design of the sensor circuit with a single output constitutes a sensor circuit which is especially cost-optimized, since a plurality of parallel outputs need no longer be made available.

In another design of the sensor circuit, the output stage has the same number of outputs as the number of different discrete switching states that must be represented. This increased number of outputs, which correlate with the various switching states, makes it possible to turn various devices on or off simultaneously and independently, corresponding to the plurality of various switching states. In this case, each output has associated with it a corresponding device. A typical application of such a sensor circuit is its use with a multi-function switch, which can turn various devices on or off individually or jointly, depending on the position of the switch lever. Another typical application of such a sensor circuit is in combination with a brightness sensor, which, with increasing darkness,

selectively turns on more and more light sources, so as always to assure sufficient illumination in an interior room. The individual light sources are here always activated selectively by their own circuit output.

Besides the two extremes of a single output and the same number of outputs as there are switching states, it is also possible for the number of outputs to lie between these extremes. This represents a compromise between the most economical sensor circuit with a single output and the technically optimized sensor circuit with many outputs, each of which is always actuated selectively.

According to a preferred design, the thresholds are made adjustable. The circuit can thus be adapted to the particular external circumstances for forming the output signal, as a function of the electrical input signal, without creating a new, corresponding sensor circuit. It is thus possible to adapt the circuit arrangement to possible time changes, such as aging effects, especially in the transducer associated with the circuit arrangement. Production tolerances or changes due to various use conditions, for example due to temperature effects and the like, can thus be taken into account very simply and economically. This considerably expands the field of application of the sensor circuit, by further increasing its functionality, without requiring complex or expensive external circuits to adapt the output signal or the input signal. This results in a very simple and

reliable sensor circuit, which is especially characterized by a very economical and flexible design.

An especially preferred design of the sensor circuit makes it possible for the user to set the thresholds himself. This can be done in a special learning mode of the sensor circuit, in which the desired switching ranges of the sensor circuit are approached, and the analytical unit, in collaboration with the control unit, determines the necessary parameters of the threshold values, and stores them in an appropriate memory, which in particular is designed as a non-volatile memory. This results in an especially flexible and very universally applicable sensor circuit, which allows the user a very large and manifold field of application.

The thresholds preferably are combined into threshold pairs, which specify a range of values with which a certain discrete switching state is associated. These threshold pairs preferably are closely spaced, so that the range in between, which does not necessarily have a particular switching state associated with it, is kept very narrow. In this way, the sensor circuit generates clear and defined switching states over nearly the entire measurement range of the analog physical variable. The choice of threshold pairs makes it possible, in a simple way, to characterize uniquely and very reliably circuit switching states, and thus to design a very reliable sensor circuit.

The sensor circuit with the threshold pairs preferably is designed so that a hysteresis exists between the individual threshold pairs. This assures that a defined switching state exists in the preferably narrow range between the individual threshold pairs. If there are frequent small fluctuations about a threshold, this assures that the sensor circuit will not constantly switch back and forth between the individual switching states, which would be undesirable. This assures that the system will assume certain switching states very reliably and persistently.

The sensor circuit preferably is designed such that it ignores brief changes of the input signal and does not consider these for changing the switching signal. Such a design does not indeed prevent short-term noise signals, which can occur again and again in an electronic circuit, whether due to electromagnetic radiation from the outside or due to switching interferences, but it does prevent their negative effects. This can be achieved by integrating or averaging elements at the input. This makes the sensor circuit especially insensitive to noise.

The sensor circuit preferably is designed as an integrated circuit, which is especially advantageous as regards EMC compatibility and small size. In particular, a sensor circuit with an integrated transducer in the form of an integrated circuit proves to be a complete sensor circuit, which requires very few pins, and thus also is very economical and not very trouble-prone. Furthermore, such a complete sensor circuit proves to be extremely small.

Its predestined application thus is in the automotive field, since tight spatial circumstances and special requirements for EMC compatibility prevail there.

A preferred embodiment of the invention is shown in Figure 1 in the form of a block circuit diagram, and will be described in more detail below.

The sensor circuit shown here has a transducer 1, which converts an analog physical variable, for example a temperature or a magnetic field strength or a pressure, into an electrical signal, and conducts this signal to an amplifier 2, whose amplified electrical signal is conducted to the input 6 of the analytical unit 4. The analytical unit 4 has a comparator arrangement, whose comparator thresholds can be adjusted by means of a control unit 3, which is connected to the analytical unit 4. The parameters for the thresholds of the comparators in the analytical unit 4 are stored in a memory (not shown) in the control unit 3, and are used to control the comparator thresholds.

The input signal at input 6 is conducted to the comparators in the analytical unit 4. Depending on the relationship of the input signal to the respective comparator thresholds, the analytical unit generates an appropriate output signal from the comparators and conducts this to the output stage 5. The latter transforms the signals of the analytical unit 4 into an output signal, which is distributed among the four outputs 7a, 7b, 7c, and 7d. Because there are different outputs 7a, 7b, 7c, 7d from the output stage 5, it is possible to

actuate directly four different devices or also groups of devices, connected to the outputs 7a, 7b, 7c, 7d, selectively and independently of one another. It is thus clear that, depending on the magnitude of an analog physical variable, several devices can be turned on or off by the sensor circuit, independently of one another and without complicated additional decoder circuits.

Figure 2 shows a switching process by way of example. Figure 2 shows the time progress of an analog measurement variable, in an arbitrary unit, as a solid line. This analog measurement variable falls from the value 1 to its lowest point just below 0.4, and then again rises to a value of about 1. Three pairs of thresholds are shown, namely A11, A21; A12, A22; A13 and A23, such that:

$$A11 < A21 < A12 < A22 < A13 < A23$$

The circuit diagram shows the progress of the output signal, which is shown as a dashed line. The output signal shows three different, discrete switching states, the switching state 1, 2, and 3. If the analog measurement variable lies within the interval A11 to A21, the diagram shows the switching state 1. If the analog measurement variable lies in the threshold interval between A12 and A22, the output signal assumes the switching state 2. If the analog measurement variable lies within the threshold interval A13 to A23, it assumes the switching state 3.

Furthermore, the diagram shows that a hysteresis exists between the threshold intervals formed through the threshold pairs. This assures that, when the analog measurement variable falls from an analog value within the interval A13 to A23 to below the limit A13, the measurement state is retained, until the upper limit of the next threshold interval A12, A22 is reached. Only when the analog measurement variable falls to the threshold A22, does the signal change from the switching state 3 to the switching state 2. The like applies to a further drop to the threshold A21, where the signal then changes from switching state 2 to switching state 1. The like also applies to a rise of the analog measurement variable, where the original switching state is retained until the lower limit of the next threshold interval is reached. This means that, when the analog measurement variable rises from a value 0.4, corresponding to the threshold A11, across the threshold A21 until it reaches the lower threshold A12, the switching state 1 is retained, even though the threshold interval A11 to A21, corresponding to the actual switching state 1, has been left behind. Upon reaching the threshold A12, the signal assumes the switching state 2, and this is retained during a further rise of the analog measurement variable, until this reaches the threshold A13. Then there is a transition from the switching state 2 to the switching state 3.

This structure of the thresholds as three threshold pairs, which are respectively connected to one another through a hysteresis region, makes it possible to represent very

reliably three discrete switching states as a function of a varying analog measurement variable. The presence of hysteresis regions in particular assures a definite switch between the individual switching states and thereby prevents undesirable frequent switching when there are fluctuations about a threshold. This makes the sensor circuit into an especially reliable and readily handled circuit arrangement, which can uniquely represent a plurality of discrete switching states.

Figure 3 shows a similar circuit arrangement as Figure 1. However, the circuit now has a single output terminal 7a, from which the various switching states of the electrical signal can be picked off in coded form. This single output terminal 7a can also be used as the input terminal for adjusting the thresholds.